

Marginal Sealing Ability of Glass Carbomer Cement with Application of Two Different Coatings: In-vitro Comparative Study



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Abstract— Background: The marginal integrity of sealing materials is key to the success of any restorative treatment. Microleakage is the primary factor responsible for the failure of Class V restorations. This study aimed to evaluate the occlusal and cervical sealing ability of Glass Carbomer versus Midfil (Conventional glass ionomer) in the restoration of class V cavities with the application of different coating materials. **Results:** After 72 hrs (3 days); occlusal and cervical micro-leakage of different restorations was statistically significant. GP II revealed the highest significant occlusal micro-leakage (60%), while GP IV showed no micro-leakage. Regarding the cervical micro-leakage, Group II and Group III showed the highest micro-leakage. However, GP IV showed the least significant leakage. After 720 hrs (1 month), the Occlusal and cervical micro-leakage of different restorations was statistically non-significant (P-value = 0.294, 0.113). **Conclusions:** Carbomer exhibited a higher degree of micro-leakage than Midfil glass-ionomer. Manufacturers' instructions should be strictly followed using a specific protective coat for each material.

Keywords: Marginal seal, microleakage, Nano Glass Carbomer, conventional Glass Ionomer, Class V cavities.

INTRODUCTION AND REVIEW

The marginal integrity of sealing materials is key to the success of any restorative treatment. Lack of sealing allows for marginal leakage, which is considered a major problem in operative dentistry ¹. The performance of the material is crucial for the integrity and durability of the marginal sealing, especially in cavities involving the cementum ².

Microleakage is the primary factor responsible for the failure of Class V restorations. The inability of the restorative materials to attain a complete marginal seal leads to the

development of micro gaps through which the seepage of fluids, ions, and bacteria occurs; this results in the development of secondary caries, hypersensitivity, and pulpal infections ³.

Restorative materials such as glass ionomers, hybrid ionomers, composite resins, and compomers are commonly used to restore Class V cavities ³. Glass ionomers are commonly used as dental restorative materials, liners and bases, fissure sealants, and bonding agents. They have several advantages (such as adhesion to the tooth structure, biocompatibility, long-lasting fluoride release, and simple clinical operation) and disadvantages (such as moisture sensitivity, low mechanical strength, and compromised aesthetics) ⁴.

The properties of smart materials may be altered in a controlled fashion by various stimuli, such as stress, temperature, moisture, pH, and electric or magnetic fields ². These materials are highly responsive and have the inherent ability to sense and react according to changes in the environment; hence, they are also called “responsive materials.” The quest for an “ideal restorative material” led to the development of a new generation of materials termed as “smart materials” owing to the support they provide to the remaining tooth structure, which aids in the conservative preparation of the cavity ⁵.

Davidson first suggested the smart behavior of glass ionomer cement (GIC), which is related to the ability of a gel structure to absorb or release the solvent rapidly in response to a stimulus, such as the temperature or pH. The smart ionomer mimics the behavior of human dentin. Additionally, resin-modified glass ionomer cements, compomers, and giomers have been reported to exhibit these smart characteristics ⁵.

Smart characteristics have been exploited in a new type of glass ionomer material known as glass carbomer, which is formulated using hydroxyapatite (HA) as a secondary filler⁶. HA has excellent biocompatibility and a crystalline structure similar to that of apatite in human dental hard tissues (enamel-like). The incorporation of HA and fluoro-apatite (FA) into GIC might not only improve the biocompatibility of GIC, but also enhance its mechanical properties. Moreover, this modified GIC can form a strong bond with the tooth structure due to its inherent similarity to the enamel and dentine ⁷.

Glass carbomer cement is biocompatible during the entire operating cycle. It exhibits excellent chemical bonding to the enamel and dentin, which ensures a proper seal at the margins. Furthermore, nano-fluorapatite particles allow for the acceleration of the remineralization process⁸. Thus, the application of the surface glass and the photopolymerization of this new material may increase the compressive strength and improve the sealing properties of this material⁹.

AIM OF THE STUDY

The aim of this study was to evaluate the sealing efficiency of a glass carbomer cement in occlusal and cervical cavities prepared in permanent posterior teeth. Additionally, the effects of different protective surface coatings (SC) on the microleakage and marginal integrity of the glass carbomer cement were assessed. The null hypothesis tested were as follows: (1) the

sealing efficiency of glass carbomer cement is higher than that of a Medifil GIC restoration in the occlusal and cervical cavity margins, and (2) the microleakage and marginal integrity of the glass carbomer cement is not influenced by the application of the different protective SC.

MATERIAL AND METHODS

Materials

A nano-hydroxyapatite reinforced glass ionomer (glass carbomer) with a coating (GCP Glass Fill, GCP Dental, Vianen, Netherlands) and a conventional high viscosity glass ionomer (Medifil) with coating and glaze (ProMedica, Neumunster, Germany) were used in the study.

Ethical approval

The study was approved by the Medical Research Ethical Committee of the National Research Centre (reference number: 19-036).

Teeth selection

A total of 80 extracted sound human premolar teeth were collected from the hospital of the National Research Center. After removing the pulp tissues, the teeth were thoroughly washed with water and cleaned with a periodontal scaler to remove the blood, attached periodontal tissues, plaque, and calculus. Subsequently, they were disinfected, rinsed, and stored in distilled water until further use.

Sample preparation

Class V cavities (mesiodistal, 3 mm; inciso-gingival, 1.5 mm; and depth, 1.5 mm) were prepared lingually and buccally using the conventional bur technique. All cavities were prepared by one operator using a high-speed hand-piece with a # 2 carbide round bur to obtain the depth of the preparation; a large # 8 round bur was used to increase the width of the preparation.

rouping of samples

The samples 80 premolars with 2 CL V cavities each labially and lingually (n = 160) were equally divided into four groups by an individual other than the one who conducted the work. The samples were placed in dark, well-sealed envelopes and sequentially numbered. A computer-generated randomization list (random sequence generator; www.random.org) was used to divide the envelopes into four groups (n = 40 in each group) according to the type of filling material and surface coating used:

Group I: Glass carbomer cement and surface coated with carbomer glaze (SCC).

Group II: Glass carbomer cement and surface coated with Medifil glaze (SCM).

Group III: Medifil GIC and SCC.

Group IV: Medifil GIC and SCM.

All the tested materials were applied by a calibrated operator according to the manufacturer's instructions. For the glass carbomer cement, photo-polymerization of the material and the application of the glaze was accomplished using a GCP Carbo-LED Curing Light (3M ESPE,

Seefeld, Germany), whereas photo-polymerization of the Medifil Glass Ionomer glaze was performed using LED (Elipar Freelight) curing units (3M Espe, St. Paul, MN, USA).

Microleakage assessment

The microleakage was assessed after 72 (3 days) and 720 (1 month) hours of storage in artificial saliva. All teeth were coated with two coats of nail polish, except for a 1 mm area around the restoration margins, and the root apices were sealed with wax (Fig. 1). The teeth were immersed in 2% methylene blue dye at room temperature for 24 h. After removal from the dye, the teeth were washed under tap water for 5 min and dried with sterile gauzes and air from an air syringe. Each tooth was sectioned vertically in the inciso-gingival direction through the center of the restoration and divided into two halves using a diamond disk at low speed under a coolant.



Figure 1. A conventional Class V cavity on the buccal and lingual surface of a premolar tooth.

All the tooth surfaces were covered with nail polish except for the 1 mm area around the restoration margins. The root apices were sealed with wax.

Microscopic analysis

The penetration of the dye into the occlusal and cervical margins in each section was evaluated using a dental surgical microscope (M320 F12 with LED) at a magnification of 25 \times . The penetration was scored as described previously¹⁰; 0: no dye penetration, 1: dye penetration up to 1/3 of the cavity depth, 2: dye penetration up to 2/3 of the cavity depth, 3: dye penetration into the depth of the cavity, but not alongside the axial wall, and 4: dye penetration alongside the axial wall (Fig.2).

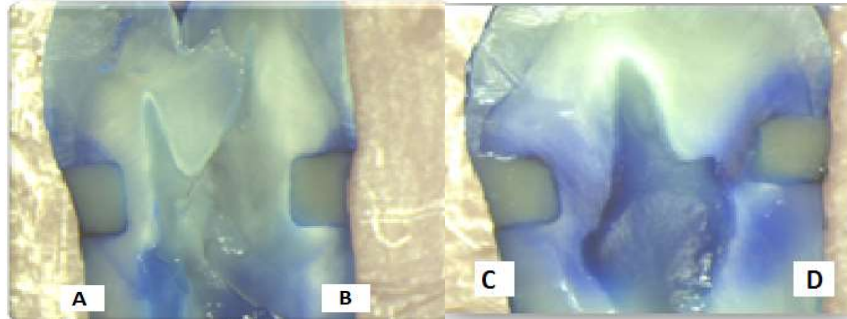


Figure 2. Microscopic image of dye penetration. A. Score 0, occlusal microleakage and score 3 cervical microleakage. B. Score 2 occlusal microleakage and score 1 cervical microleakage. C. Score 0 occlusal microleakage and score 4 cervical microleakage. D. Score 0 occlusal microleakage and score 1 cervical microleakage.

Statistical analysis

The statistical analysis was performed with IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 22 for Windows. All data were tabulated, statistically analyzed, and presented as mean and standard deviation values. The Kruskal-Wallis test was used to compare the marginal gaps among the different tested groups, and the Wilcoxon signed-rank test was used to compare the follow-up periods for each Material for Marginal leakage. The significance level was set at $P \leq 0.05$.

RESULTS

Marginal leakage (Occlusal margin)

Effect of different Materials

- At 72 h (3 days):

The frequency (n) and percentage (%) of marginal leakage in the occlusal margins in the different tested materials at 72 h (3 days) are shown in Table 1 and Figure 3. Significant differences in occlusal microleakage were observed among the different restorations; the samples in Group II presented with the highest occlusal microleakage (60%; grade 4), and those in Group IV demonstrated the least occlusal leakage (0%; grade 0).

Table 1. Frequency (n) and percentage (%) of the marginal leakage in the occlusal margins of the different tested materials after 72 h (3 days).

Group	Marginal leakage (Occlusal margin)										P-value
	72 h (3 days)										
	0		1		2		3		4		
	N	%	n	%	n	%	n	%	n	%	
I	10	50.0%	2	10.0%	2	10.0%	4	20.0%	2	10.0%	0.011*
II	0	0.0%	2	10.0%	6	30.0%	0	0.0%	12	60.0%	
III	8	40.0%	6	30.0%	0	0.0%	0	0.0%	6	30.0%	
IV	12	60.0%	2	10.0%	2	10.0%	4	20.0%	0	0.0%	

Means with the same letter within each column are not significantly different. * $p < 0.05$

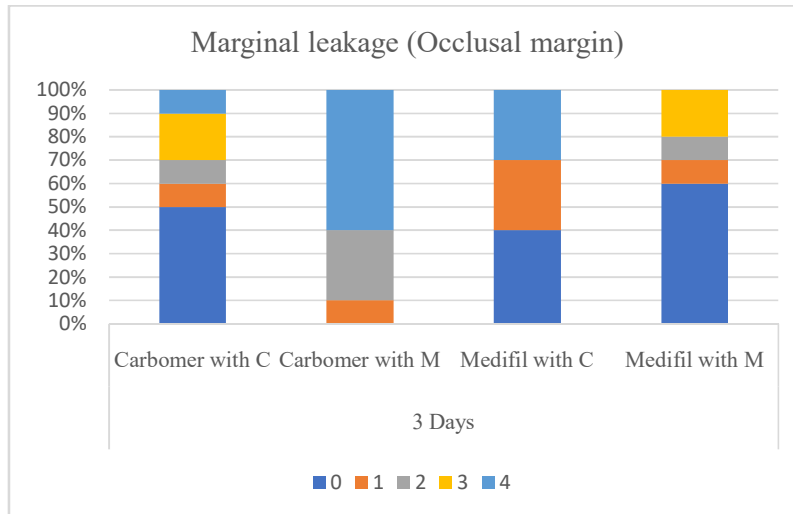


Figure3. Histogram showing the percentage (%) of marginal leakage (occlusal margin) in the different tested materials after 72 h.

- At 720 h (1 month):

The frequency (n) and percentage (%) of marginal leakage in the occlusal margins of the different tested materials after 720 h (1 month) are shown in Table 2 and Figure4. No significant differences in microleakage were observed among the materials.

Table 2. Frequency (n) and percentage (%) of marginal leakage (occlusal margin) in the different tested materials after 720 h (1 month).

Group	Marginal leakage (Occlusal margin)										P-value
	720 h (1 month)										
	0		1		2		3		4		
	N	%	n	%	N	%	n	%	n	%	
I	2	10.0%	4	20.0%	12	60.0%	0	0.0%	2	10.0%	0.294 NS
II	6	30.0%	0	0.0%	6	30.0%	2	10.0%	6	30.0%	
III	8	40.0%	0	0.0%	0	0.0%	10	50.0%	2	10.0%	
IV	12	60.0%	4	20.0%	0	0.0%	2	10.0%	2	10.0%	

* p < 0.05. NS, non-significant

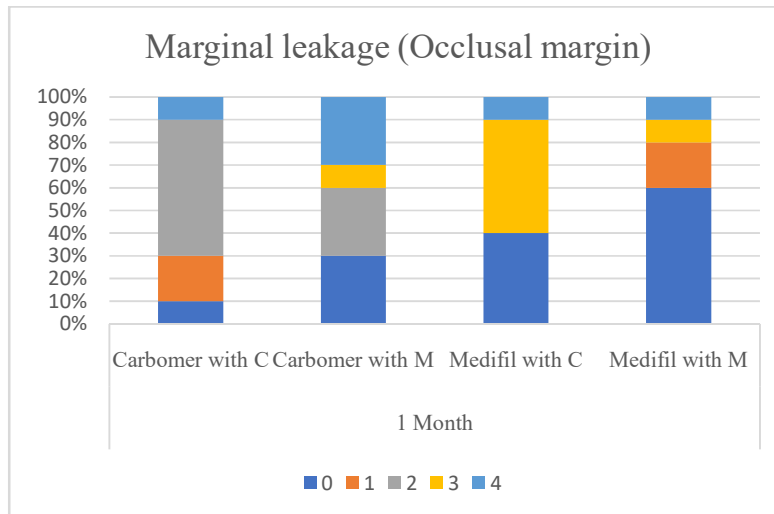


Figure 4. Histogram showing the percentage of marginal leakage (occlusal margin) in the different tested materials after 720 h (1 month).

Effect of follow-up periods:

Comparisons of the frequencies and percentages of marginal leakage (occlusal margin) associated with each material during two follow-up periods are presented in Table 3 and Figure 5. No significant differences in marginal leakage were observed between the two follow-up periods in the various groups, except for Group II, in which frequencies and percentages of marginal leakage at 72 h (3 days) interval was statistically higher than that of 720 h (1 month) interval.

Table 3. Comparison of the frequency (n) and percentage (%) of marginal leakage (occlusal margin) during the different follow-up periods for each material.

Group	Marginal leakage (Occlusal margin)																		P-value			
	72 h (3 days)									720 h (1 month)												
	0		1		2		3		4		0		1		2		3			4		
	n	%	N	%	N	%	N	%	N	%	rankin	n	%	n	%	N	%	n		%	n	%
GP I	10	50%	2	10%	2	10%	4	20%	2	10%	ab	2	10%	4	20%	1	5%	0	0%	2	10%	0.334
GP II	0	0%	2	10%	6	30%	0	0%	1	5%	a	6	30%	0	0%	6	30%	2	10%	6	30%	0.041*
GP III	8	40%	6	30%	0	0%	0	0%	6	30%	ab	8	40%	0	0%	0	0%	1	5%	0	0%	0.778
GP IV	12	60%	2	10%	2	10%	4	20%	0	0%	b	12	60%	4	20%	0	0%	2	10%	2	10%	1.000

P-value	0.011* for column	0.294 NS for columns	
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Means with the same letter within each column are not significantly different. *p<0.05. NS, non-significant.

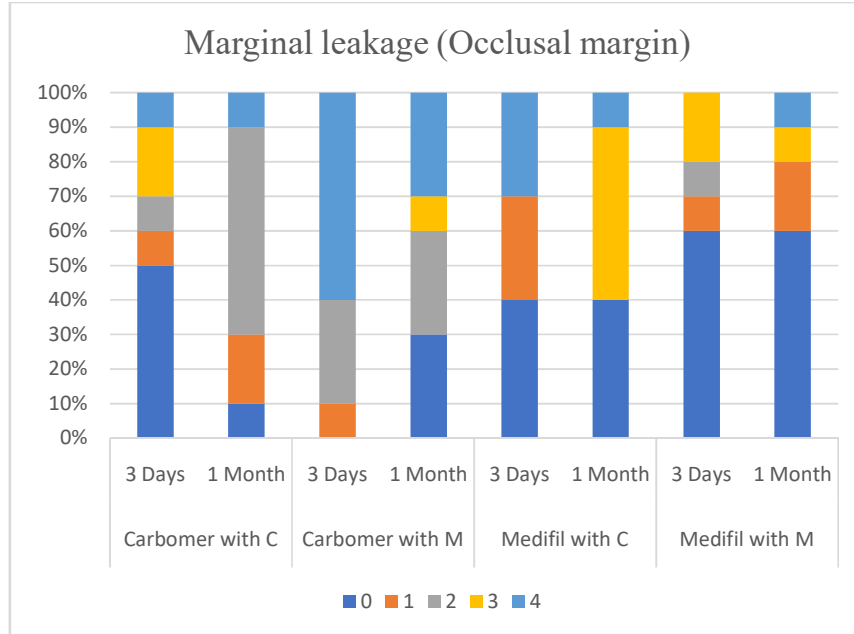


Figure5. Histogram showing the percentage of marginal leakage (occlusal margin) during the two different follow-up periods for each material.

Marginal leakage (Cervical margin)

Effect of different materials

- At 72 hrs (3 days):

The frequencies and percentages of marginal leakage in the cervical margin for different materials at 72 h (3 days) are presented in Table 4 and Figure6. Significant differences in cervical microleakage were observed among the different restorations; Group II and Group III showed the highest microleakage, whereas Group IV presented with the least leakage.

Table 4. Frequency (n) and percentage (%) of marginal leakage (cervical margin) in the different tested materials at 72 h (3 days).

		Marginal leakage (Cervical margin)										P-value
		72 h (3 days)										
		0		1		2		3		4		
		N	%	n	%	n	%	n	%	n	%	
Group	Group (I)	0	0.0%	2	10.0%	0	0.0%	8	40.0%	10	50.0%	0.029*
	Group (II)	0	0.0%	2	10.0%	0	0.0%	4	20.0%	14	70.0%	
	Group (III)	0	0.0%	0	0.0%	4	20.0%	2	10.0%	14	70.0%	
	Group (IV)	4	20.0%	4	20.0%	4	20.0%	4	20.0%	4	20.0%	

*p < 0.05

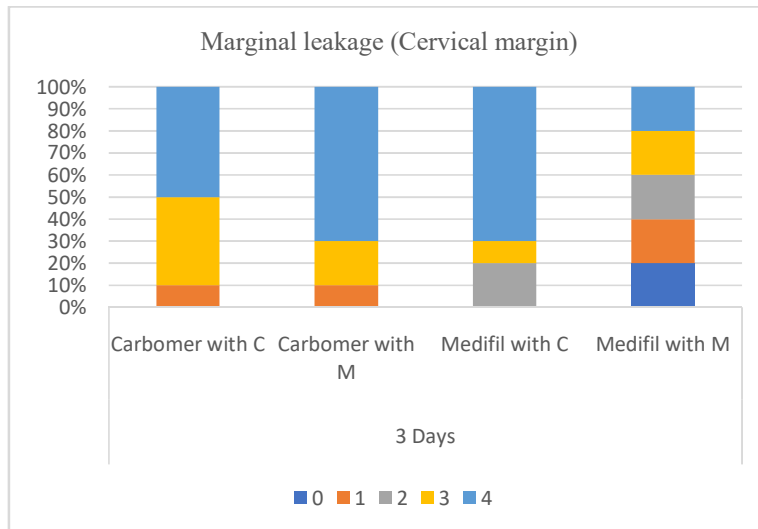


Figure 6. Histogram showing the percentage of marginal leakage (cervical margin) in the different tested materials at 72 h (3 days).

- At 720 h (1 month):

No statistically significant differences in the frequencies and percentages of marginal leakage in the cervical margins were observed among the tested materials at 720 h (Table 5 and Figure. 7).

Table 5. Frequency (n) and percentage (%) of marginal leakage (cervical margin) for different tested materials at 720 h (1 month).

		Marginal leakage (Cervical margin)										P-value
		720 h (1 month)										
		0		1		2		3		4		
		n	%	n	%	n	%	n	%	n	%	
Group	Group (I)	0	0.0%	0	0.0%	2	10.0%	4	20.0%	14	70.0%	0.113 NS
	Group (II)	4	20.0%	4	20.0%	6	30.0%	0	0.0%	6	30.0%	
	Group (III)	0	0.0%	8	40.0%	0	0.0%	4	20.0%	8	40.0%	
	Group (IV)	2	10.0%	2	10.0%	2	10.0%	4	20.0%	10	50.0%	

p < 0.05. NS, non-significant.

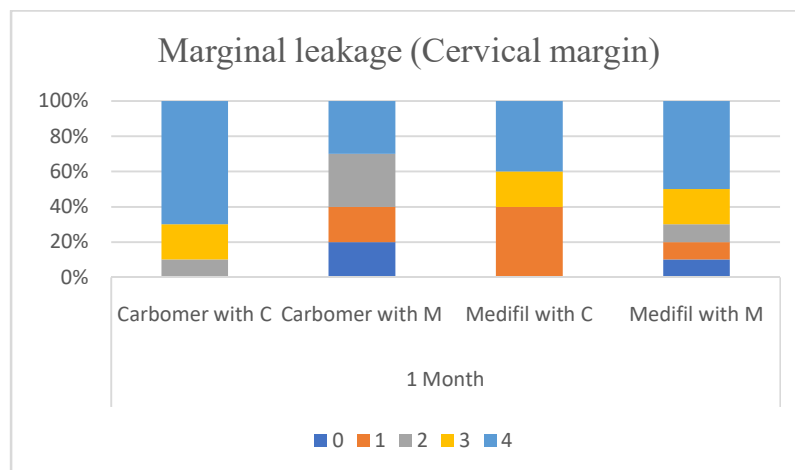


Figure 7. Histogram showing the percentage of marginal leakage (cervical margin) for different tested materials at 720 h.

Effect of follow-up periods

Comparisons of the frequencies and percentages of marginal leakage at the cervical margin in the four groups during the two follow-up periods revealed no significant differences, except for Group II, in which frequencies and percentages of marginal leakage at 72 h interval was statistically higher than that of 720 h (Table 6 and Figure 8).

Table 6. Comparisons of the frequencies (n) and percentages (%) of marginal leakage (cervical margin) during the two follow-up periods for each material.

	Marginal leakage (Cervical margin)																p-value					
	72 h (3 days)								720 h (1 month)													
	0		1		2		3		4		0		1		2			3		4		
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%		n	%	n	%	
GP I	0	0%	2	0%	0	0%	8	40%	1	50%	0	0%	0	0%	2	0%	4	0%	1	4	70%	0.527 NS
GP II	0	0%	2	0%	0	0%	4	20%	1	4	70%	4	20%	4	0%	6	0%	0	0%	6	30%	0.027*
GP III	0	0%	0	0%	4	20%	2	10%	1	4	70%	0	0%	8	0%	0	0%	4	0%	8	40%	0.154 NS
GP IV	4	20%	4	20%	4	20%	4	20%	4	20%	2	0%	2	0%	2	0%	4	0%	1	0	50%	0.216 NS

* p < 0.05. NS, non-significant.

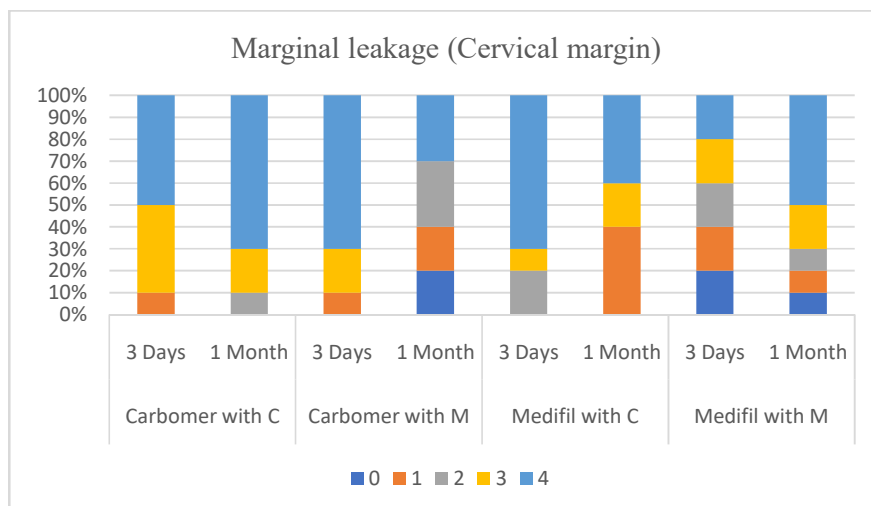


Figure 8. Histogram showing the percentage of marginal leakage (cervical margin) during the two follow-up periods for each material.

DISCUSSION

The microleakage sealing ability of the carbomer glass cement was assessed using the dye penetration method and compared with that of a conventional GIC. Various methods have been described to compare the sealing efficiencies of restorative materials. A dye penetration test is usually used because it is generally precise in assessing the marginal sealing, it is simple and easy to perform, and it allows for the direct reading of the diffused marker under the microscope¹¹. The dye penetration method has many advantages over other techniques; first, no reactive chemical or radiation is used. Second, the method is highly feasible and easily reproducible; the most commonly used solutions are 0.5% basic fuchsin, 2% methylene blue, and 50% silver nitrate. Methylene blue was used as the dye in the current study because it is easily detectable, can readily diffuse through the interface, and is not absorbed by the dentinal matrix hydroxyapatite crystals. It has a high penetrability and can penetrate the voids better than isotopes owing to its relatively lower molecular weight³.

The carbomer restoration was developed to overcome the drawbacks of conventional GIC. The carbomer was based on two concepts to enhance the bonding with the tooth structure and improve the marginal sealing ability: the first concept was to develop a biomimetic (enamel-like) material, and the second was to use high-energy light to hasten the setting reaction of the glass ionomer. The results of this study revealed that the samples in Group IV (Medifil GIC coated with Medifil glaze) presented with the least occlusal and cervical microleakage, whereas Group II (carbomer coated with Medifil glaze) showed the highest amount of microleakage. The chemical reaction of the carbomer was initiated by the ionization and release of calcium, phosphorous, and fluoride ions. Oversaturation of the media resulted in ion exchange with the tooth hydroxyapatite crystals, followed by ion consumption in order to build up the HA crystals with tooth crystals. The consumed apatite in Carbomer could be associated with the interactions in the carboxylic groups, which could lead to a decrease in the available ions to bond with the mineral content of teeth, resulting in lower bond sealing compared to the conventional glass ionomer Medifil reaction¹².

It is crucial to coat the glass ionomer with varnish during the setting stage because water uptake and loss can compromise surface protection. The type of coating used is one of the most important factors that could affect microleakage. All types of glass ionomers are supplied with their unique varnish. The use of a carbomer with its carbomer coating sealed the initial surface cracks and improved the surface properties of the restoration. Alternatively, the use of the Medifil coating (copal varnish) to protect the carbomer restoration resulted in extensive microleakage, which might be attributed to the higher viscosity of this type of coating; the decrease in flow properties can lead to surface cracks and air pocket formation and result in poor contact with the interface. This phenomenon might explain the initial increase in microleakage in the carbomer restoration coated with Medifil coating¹³.

The difference in microleakage between the enamel (occlusal) and dentinal (gingival) margins may be due to challenges encountered with dentin surface bonding, which may be attributed to differences in the amount of inorganic hydroxyapatite in the dentin (45%) and enamel (92%). Additionally, the cementum has a reduced amount of organic material and coarser collagen fibers, which makes it a weaker bonding substrate³. The properties of the dentin interface, which include the fluid pressure, low surface energy, and presence of parallel tubules that run toward the pulp, make it challenging to achieve a proper bonding¹⁴.

Thus, the two hypotheses in the present study were rejected because the extent of cervical and occlusal microleakage in the carbomer restoration was greater than that in the Medifil (conventional glass ionomer) restoration; additionally, changing the type of coating negatively affected the microleakage.

SUMMARY AND CONCLUSIONS

This study aimed to evaluate if the sealing efficiency of glass carbomer cement is higher than that of a Medifil GIC restoration in the occlusal and cervical cavity margins of CL V cavities and if the microleakage and marginal integrity of the glass carbomer cement is not influenced by the application of the different protective surface coating, two coatings were used: carbomer glaze and Medifil glaze.

Carbomer exhibited a higher degree of microleakage than the Medifil GIC. Furthermore, the findings of this study indicated that the manufacturer's instructions should be strictly followed when using a specific protective coat for each material.

RECOMMENDATION

It is suggested that further investigation be conducted to establish a better understanding of this newly developed restorative material.

ABBREVIATIONS

GIC Glass Ionomer Cement, HA Hydroxyapatite, FA fluoro-apatite, SC surface coatings, SCC surface coated with carbomer glaze, SCM surface coated with Medifil glaze, NS non-significant.

ACKNOWLEDGMENTS

None are declared.

AUTHORS' CONTRIBUTIONS:

HAS and GS participated in the design and coordination of the study, analyzed data, and contributed to the drafting and preparation of the manuscript. HS and GS participated in performing experiments and analyzing data. HS and SMM helped to edit the manuscript. All authors read and approved the final manuscript.

FUNDING:

None are declared.

AVAILABILITY OF DATA AND MATERIAL:

Analytic methods and study will be made available on publication of this research article. The data supporting the results of this study are existing within the article.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE:

The study was approved by the Medical Research Ethical Committee of the National Research Centre, reference number: (19-036).

CONSENT FOR PUBLICATION:

Not applicable.

COMPETING INTERESTS:

No competing interests.

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